Clustering the Roman Empire: the use of multivariable analysis to understand cultural dynamics

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Abstract- *The aim of this study is to analyze the effects of rates of change of the olive oil amphorae to explore the production dynamics in the Roman Empire. In this case Cultural Evolution theory will be applied to the material culture study because is considered a useful tool to understand the variability of the mechanisms of changes. This analysis can be developed by the fact that we detect differences in the amphorae production through time that they might explain this dynamic of change.*

In this context, it will be presented a research where this methodology has been used to show its capacity to detect the culture trajectories. In particular, our case of study has been focused to understand the dynamics of change of olive oil amphorae production found in Baetica (currently Andalusia) during the Roman Empire (1st-3rd century AD). Specifically, multivariable methods have been applied to distinguish pottery assemblages among different kinds of shapes that it could serve to identify discontinuities in archaeological sequences. Specifically, we want to identify if these changes were produced by cultural reasons as it may be economical, political and social changes.

Finally, the results suggest that different factors as spatial distance can influence the rate of change and that rates will be more or less likely depending on them.

I. INTRODUCTION

Cultural evolution theories [1] provide a set of methods that can be used to account these dynamic of changes, focused on the production of olive oil amphorae during the Roman Empire.

To achieve this goal, multivariable methods were used to evaluate the differences on the pattern production among pottery workshops [2].

Fig. 1. Distribution map of the four amphorae workshops. The names are Las Delicias (Écija, Seville), Belén and Malpica (Palma del Río, Córdoba) and Parlamento (Seville)

Specifically we want to identify the origin of these changes and if these changes were produced by cultural reasons depending on the spatial distance and other cultural constraints. As hypothesis, we propose that spatial distribution of pottery workshops is the main influence of the making techniques processes [3]. Four pottery workshops, showed in the map (fig.1) were studied from different spaces in *Baetica*.

II. METHODS

A. *Measurements*

To explore the dynamic of changes we analysed a set of measures among different kinds of amphorae shapes from different workshops. We analysed 413 samples of amphorae from 4 different workshops. These workshops were selected from different spaces of *Baetica* area in order to know if there were differences depending on the space. A database was created using a selection of 80 to 90 samples from each pottery workshops. In each sample of amphora we measured eight measurements among different part of the rim being focused on the rim of the amphora.

B. *Multivariable methods*

Multivariable methods were used to explore these metrical observations [4] with the eight measurements as variables. Principal Component Analysis allowed us to simplify the dataset to see which variable were more relevant. Our results suggested that first and second principal component were more relevant than the rest.

III. RESULTS

Several multivariable methods were used such as [illegible] and Discriminant Analysis to classify. These methods allowed us to know the differences on the pattern production among workshops. In our case, the first two principal components were taken to see the significal differences among workshops depending on the space. The figure 2 shows the workshops with a minor space such Belén and Malpica share more pottery traits than the rest: Parlamento and Las Delicias.

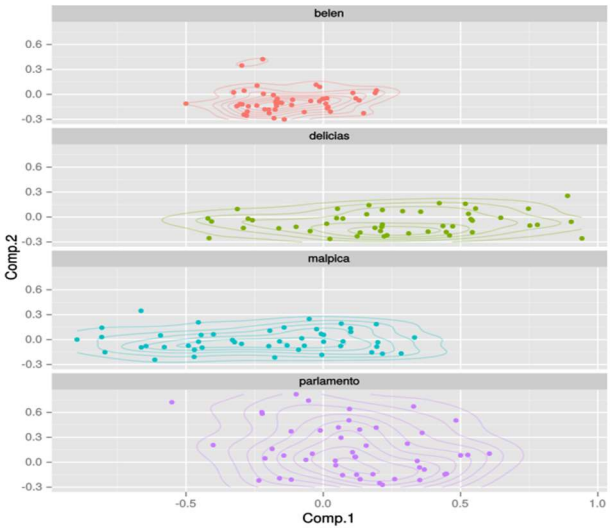

Fig. 2. Plot with the results of the first two principal components given by the PCA.

Once defined the components, we used Discriminant Analysis to find a combination among them to define the groups as well as possible. These results were translated to a confusion matrix which basically means what results were predicted as true or false on the discriminant analysis. As shown in the Figure 3 of confusion, all correct guesses were located in the diagonal of the table. Thus the system had troubles to distinguishing between Belen and Malpica which had a higher number of confusion or number instead of Parlamento with a minor confusion than the rest.

	BELEN	DELICIAS	MALPICA	PARLAMENTO
BELEN	**37**	10	18	8
DELICIAS	4	**32**	8	14
MALPICA	5	3	**18**	6
PARLAMENTO	2	3	4	**20**

Fig. 3. Matrix of confusion. Accuracy: 0.5573 %. P-Value: 0.0006991.

A peer to peer comparison was developed among different workshops. We calculated the geographical distance between each site and the distance among pottery measures, calculated using the previous results. The Figure 4 shows that the pottery distance is correlated with the spatial distance of workshops.

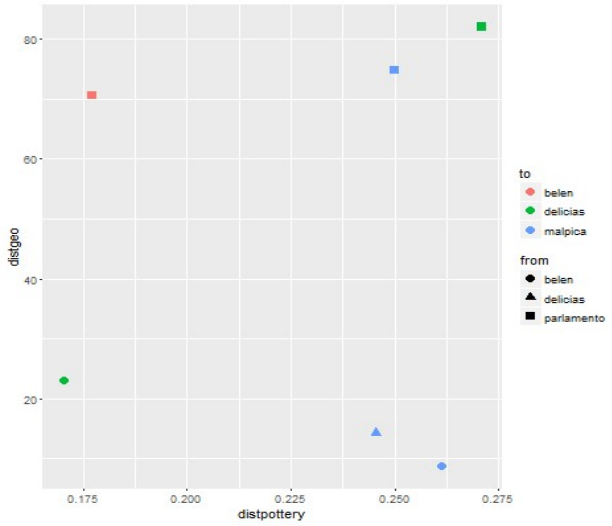

Fig. 4. Distance metrics calculated among different workshops.

CONCLUSION

Differences among pottery workshops were identified using PCA and Discriminant Analysis. As results, Amphorae made in nearby workshops with a minor spacial distance, such as Malpica and Belen, share more traits than amphorae made in pottery workshops farther as Parlamento. It could suggest that the pottery techniques were learned from master to disciple instead of workers with the same level.

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